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Contractor's Report

To The Board

Landfill Gas Monitoring Well Functionality at 20 California Landfills

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Executive Summary

The intent of the study is to evaluate the functionality of landfill gas (LFG) perimeter migration monitoring probes; in other words, that the monitoring data collected is representative of the actual soil gas conditions in the vicinity of the screened portion of each probe.

CIWMB preselected 20 landfill sites in northern and southern California to be included in this study. The landfills were selected to include a variety of landfill sizes, geomorphic and geologic settings, and the presence of relatively deep gas probes (40 to 99 feet, or more). Ten probes at each landfill were selected by the contract manager for functionality review and determination. For purposes of this report, we refer to each drilled hole as a well and each individually installed section of PVC as a probe. This report details the on-site activities associated with the functionality assessment and discusses the combined results as they relate to a determination of the overall functionality of each probe at each of the 20 landfill sites.

In order to implement the Functionality Study, a standardized approach to probe functionality assessment was developed prior to implementation of the field portion of the Functionality Study.

The standardized approach for probe assessment consisted of the following activities:

- **Pre-Assessment Activities,** which consisted of pre-notification of site owners/operators, on-site random selection of probes, and recording of ambient conditions (pressure, weather, etc.).
- **Initial Condition Assessment,** which consisted of reviewing the geographic location of the probe, reviewing the identification methodology for the probe, assessing the probehead assembly (fittings, piping, etc.), and conducting surface emissions monitoring in the vicinity of the probe.
- **Gas Monitoring Assessment,** which consisted of recording initial pressure readings, LFG monitoring, ambient oxygen analysis, depth trend analysis, and methane concentration analysis.
- **Vacuum Testing** of the probe, which consisted the application of a known vacuum to a probe and recording the probe response once the vacuum was stopped.
- **Video Borescope Inspection,** which consisted of verifying the probe construction by creating a video log of the inside of the probe using a small diameter borescope.
- **Lithology Evaluation,** which consisted of the evaluation of the adequacy of the placement of the screened section of a probe considering permeable and porous lithologies.

As discussed in the report, there is no single way in which to evaluate the functionality of a probe. It is through a combination of observations that probe functionality can be determined. For each probe evaluated under this study, SCS reviewed the results from the various components of the sampling program and made a determination as to the probe's functionality for compliance monitoring purposes. The results of this assessment are provided in Table 2 (Appendix B).

As shown in Table 2, there were a total of 61 probes identified as non-functional, 12 probes identified as "indeterminate," and 117 probes identified as functional.

Based upon this study, the current approach to LFG perimeter migration monitoring probe design, construction, and installation is unsatisfactory. An industry/regulatory standard should be set for probe construction and installation.

Introduction

SCS Engineers (SCS) is pleased to submit this report to the California Integrated Waste Management Board (CIWMB) on the study of existing landfill gas (LFG) perimeter migration monitoring wells (probes) located at various landfills throughout the State. For purposes of this report, we refer to each drilled hole as a well and each individually installed section of PVC as a probe. Therefore, a typical perimeter migration monitoring well will consist of two or more nested probes.

The intent of the study is to determine the functionality of perimeter migration monitoring probes; that is to say, that the monitoring data collected is representative of the actual soil gas conditions in the vicinity of the screened portion of each probe.

Ten probes at each landfill were selected randomly for functionality review and determination. This report details the on-site activities associated with the functionality assessment and discusses the combined results as they relate to a determination of the overall functionality of each probe at each of the 20 landfill sites.

Because a significant number of gas monitoring probes were determined to be non-functional for purposes of LFG migration monitoring and assessment, it would tend to indicate that landfill gas migrations may be underestimated or undetected at a larger number of California sites, potentially leading to dangerous conditions for people and facilities located near landfills and adverse effects on the environment. Therefore, based on the results and conclusions drawn from this study, existing regulations may need to be enhanced to ensure that monitoring probes installed around landfills are functional and capable of detecting migrating LFG in accordance with the California Code of Regulations (CCR) Title 27, §20919.5.

The assessment of landfill gas monitoring well functionality that has been completed under this study focused on visual and physical testing of 190 landfill gas probes located at 20 sites in California.* All monitoring and testing has been conducted in accordance with the methods in the approved work plan dated November 2006, which is included as Appendix A.

Project Objectives and Approach

CIWMB selected 20 landfill sites in northern and southern California to be included in this study. The landfills were selected to include a variety of landfill sizes, geomorphic and geologic settings, and the presence of relatively deep gas probes (40-99 feet). These deeper probes have the greatest potential for installation problems, ground water infiltration, or other conditions that could render them ineffective monitoring points. Table 1 (listed in Appendix A) presents a listing of the landfills included in the study.

SCS reviewed internal files regarding the sites selected by CIWMB to determine if landfill gas probe information existed for these sites in the SCS files.

* A total of 200 probes (10 at each site) were evaluated; however, 10 probes were deemed to be non-applicable for this study due to probe construction (e.g., assembled with screws) or probe depth beyond the study's equipment limitations.

Data of concern included:

- Locations of probes
- Construction details and as-built diagrams
- Completion depths
- Gas monitoring history
- Well boring logs

After obtaining as much data as possible from the SCS files, a data request was made to CIWMB for missing data. This included those sites for which SCS did not have any data, or for portions of data not in our files.

The actual probes to be investigated at each landfill were selected by CIWMB staff, at each site, on the day or days of each site study.

Probe Functionality Assessment

SCS developed a standardized approach to the review and assessment of each of the 20 landfill sites located throughout the State, working in concert with CIWMB. The project was broken into northern and southern regions, with 10 landfill sites located within each region. Our general approach to data collection at each site, along with a narrative of our findings is presented below.

Pre-Assessment Activities

Pre-Notification and On-Site Arrival

Prior to the planned arrival date for each landfill, CIWMB personnel contacted the landfill operator to coordinate on-site activities. In some cases, the owner/operator wished to have a representative present during the probe study, so arrangements were made to accommodate this representative.

Selection of Gas Probes

Upon arrival at each landfill, CIWMB staff selected the probes to be investigated after meeting with on-site officials and considering the age, depth, and accessibility of the probes.

Ambient Conditions

At each landfill site, prior to the assessment of each LFG migration monitoring well, SCS recorded ambient atmospheric conditions including weather, barometric pressure, temperature, wind speed, and wind direction.

Recordkeeping

All data collected for each probe investigation was recorded on a Landfill Gas Probe Field Data Sheet. A copy of the completed data sheets for each probe at each site is located in Appendix B.

Initial Monitoring Probe Condition Assessment

For each of the 20 sites included in the study, SCS performed an assessment of the initial monitoring probe conditions, consisting of an evaluation of probe location, probe identification, and probehead assembly assessment, as well as performing an assessment of surface emissions around each probe. A summary of probe-by-probe findings for the initial monitoring conditions is included as Table 2 (Appendix B). The results of this initial assessment are discussed below.

Monitoring Probe Location

For each site, SCS was provided with a map of the landfill to locate the probes to be monitored. When the mapped location of a probe was verified in the field, SCS cross-checked the map to determine if the map properly identified the true location of the probe. SCS then digitally photographed the gas probe wellhead and surrounding area. A photograph or video identification (picture number, etc.) has also been recorded on the Landfill Gas Probe Field Data Sheets (Appendix B). Of all of the probes selected for this study, only one probe (probe GP-5B at the City of Huntington Beach Landfill) was not properly located on the map.

Monitoring Probe Identification

In order to properly identify monitoring probes at a landfill, the probe should be uniquely labeled in order to distinguish it from other probes within the casing. This is typically done by sequentially numbering the well locations around the site and using a designation of “S” for shallow depth, “M” for medium depth, and “D” for deep depth probes (for triple-nested probes). In some cases this was done adequately, but during the study several inconsistencies were found which made it difficult to determine the identity of the monitoring probe. A summary of inconsistencies identified at each site is presented in Table 2 (Appendix B).

While some of the landfill sites used alternative designations that were relatively easy to interpret, as in the example of probe G-3A (shallow) and G-3B (mid-depth) at Ukiah Landfill, not all were so clear. For example, all ten probes at the City of Huntington Beach Landfill were identified using a depth designation of “Y,” “B,” and “R,” representing shallow, mid-depth, and deep probes respectively (as determined using video borescope records).

In some cases, it was apparent that probe well boxes had been exposed to the elements for some time, and any identification markings (mostly permanent marker) had worn off. SCS found that this problem was not particularly difficult to solve given a functional probe location map for the site.

However, in some cases, probes were mislabeled. For example, at Clovis Landfill, the probe labeled MMW-108M was determined to be the deep probe after the video borescope investigation (see Section 3.5). The probe labeled MMW-108D was actually the mid-depth probe. At Corral Hollow Landfill, the probe labeled GW-1S was actually the deep probe.

Based on observed probes, SCS recommends that each probe should be individually labeled with the well identification, as well as probe relative depth (shallow, mid-depth, and deep), and screened interval (i.e., MP-1; S; 7-10’, for a shallow probe, screened from 7 to 10 feet below ground surface[bgs]).

Probehead Assembly Assessment

All of the landfills monitored at the time of this study had some type of probe surface configuration which included a gas monitoring port used to periodically sample gas concentrations. Table 2 (Appendix B) contains construction details (including wellhead assembly) for probes at each landfill monitored in this study.

The probehead design assembly encountered during the study tended to vary significantly from site-to-site, and sometimes even from well to well on a single site. For most of the probes included in this study, the gas monitoring port was adequate enough to take sample readings from the probe. However, there were some cases in which proper readings could not be obtained from the probe due to improper monitoring port assembly and/or design.

For example, some of the monitoring probes at Clovis, Buena Vista, and Crazy Horse landfills had wellhead assemblies that were not adequate to take samples with the instruments that were used in this study. In order to take gas concentration readings and conduct the vacuum test on these monitoring probes, the existing probehead had to be taken off and another probehead was put on. Because the probehead was removed, initial pressure in the probe could not be obtained. (Note: Each probe that had to have the probehead replaced was given approximately five minutes to regain the static pressure that existed before the probehead was removed.)

The gas monitoring port of the probes at each landfill also varied. Table 2 (Appendix B) describes the type of cap (slip cap, threaded cap, rubber stopper, etc.) used for the valve assembly. Some port types (e.g., labcock vales and quick-connect fittings) were more conducive to valid sample collection (ability to measure static pressure in an enclosed probe, etc.), whereas other port types (e.g., bicycle valve stem, slip cap, threaded caps, rubber stoppers, open pipe, etc.) are not.

Based on observed probes, SCS has found that labcock valves and/or quick connect fittings provided the best connection for standard monitoring instruments.

Surface Emissions Monitoring

At each site, surface emissions monitoring (SEM) was conducted in order to assess the overall integrity of the wellhead and individual probe completions; in other words, surface emissions may be an indicator that subsurface gases are migrating up the well borehole, outside of the probe casing. SEM activities were conducted within a five-foot radius around each monitoring well using an RKI Eagle, calibrated to read combustible gases as methane. SEM was conducted in order to evaluate the potential for the presence of LFG due to possible inadequate probe design or probe breakage. The results of the surface emissions monitoring are included in Table 2 (Appendix B). Note that in addition to the SEM data, the inside of each well box was also monitored. (The results, if any, from this additional monitoring are included in the comments column of the initial monitoring section of Table 2.)

Generally, it appears that wellhead design of the monitoring probes at each landfill prevented escaping gases from entering the atmosphere. As shown in Table 2, surface emissions were detected at the following sites around the following wells:

- Ukiah Landfill (2 out of 4 wells; G-3 and GAS-6)
- Anderson Landfill (2 out of 5 wells; GM-6 and GM-7)
- Benton/Redding Landfill (3 out of 6 wells; GM-1, GM-2A, and GM-4A)
- Crazy Horse Landfill (1 out of 5 wells; GW-1D)
- Hillside Landfill (1 out of 6 wells; P-18)
- Kiefer Road Landfill (1 out of 7 wells; GP-44)
- Red Bluff Landfill (4 out of 6 wells; GW-3, GW-2, GW-4, and GW-7D)

The highest SEM concentrations identified were at the Crazy Horse Landfill, associated with the well box assessment of GW-1. During this assessment, methane concentrations within the well box for GW-1 were 10 percent by volume, which is within the explosive range for methane. Likely causes of significant gas detections near the ground surface outside of the probe casing may include:

- Inadequate probe completions (deteriorated bentonite seals, etc.)
- Cracks, leaks in probe casing near ground surface
- Poorly designed/opened sample ports at the time of monitoring

- Improper design of the wellhead assembly
- Location of probe in proximity to refuse footprint

Gas Monitoring Assessment

Initial Pressure Readings

Following initial condition assessment, SCS monitored each probe for initial pressure using a magnahelic or Dwyer electronic pressure gauge. This data provides an initial assessment of the subsurface environment of the probe, and can also be used to assist in determination of probe functionality. While a positive pressure reading in a probe is generally considered indicative of gas generation and migration away from the refuse mass, a negative pressure reading is generally indicative of a probe under vacuum, as may be seen with probes located in close proximity to an LFG extraction well. Note that this assertion is made notwithstanding the influence of typical (e.g., diurnal) barometric pressure fluctuations within probes. However, and more importantly, the more of a variation from ambient (zero) static pressure a probe displays, the more a probe can be relied upon as functional since, by showing either negative or positive pressure, the probe is also demonstrating that it can hold pressure.

As shown in Table 2 (Appendix B), 59.5 percent (113 out of the 190 probes monitored) had a zero pressure reading. As noted above, an initial pressure reading of zero does not indicate that the probe is non-functional.

LFG Monitoring

In addition to ambient pressure and temperature, SCS monitored each probe for methane (CH4), carbon dioxide (CO_2), and oxygen (O_2), using a Landtech Gas Extraction Monitor (GEM 2000). Probes were also monitored for carbon monoxide (CO) and hydrogen sulfide (H_2S) using an RKI Eagle multi-gas meter. For this study, readings were monitored until a steady state level was achieved for 30 seconds, where possible. Gas concentrations observed were recorded on the Landfill Gas Probe Field Data Sheet (Table 2--Appendix B).

Gas concentrations monitored from each probe should represent the concentration of gases in the soils around the screened portion of the probe. In order for gas concentration data to validate the functionality of a given probe, the concentrations of gases observed in the probe itself must be indicative of a subsurface environment (e.g., lower than ambient O_2, increased CO_2, etc.).

Ambient Oxygen Analysis

Gas concentrations within shallow probes that are not influenced by migrating LFG generally have a higher (closer to ambient) concentration of oxygen than do deeper probes. This is because air exchange with the atmosphere, under barometric influences, decreases substantially as you go deeper into the soil horizons, while natural (non-landfill) subsurface oxidation and decay of soil organics (roots, etc) increases. Further, migrating methane itself can be biologically oxidized within soil pore spaces.

Aerobic microorganisms in soils deplete the oxygen and release carbon dioxide within the soil, resulting in higher concentrations of carbon dioxide and lower concentrations of oxygen. This is especially common in the deep probes where oxygen concentrations are expected to be low. Therefore, a decrease in oxygen with depth in probe monitoring is typically considered to be indicative of a valid sample obtained from a subsurface environment, whereas near atmospheric levels of oxygen in a deep probe, while they can and do periodically occur, is generally indicative of atmosphere leaking into a probe via a crack in the casing, a break in the sampling port/sampling train, or a leak in sampling valve itself.

Of the 190 probes monitored for this study, 19.5 percent (37) had ambient levels (at or greater than 20 percent oxygen by volume) in the probe at the time of monitoring. A site-by-site summary of these probes is presented below.

- **Ukiah Landfill – 1 probe**
  GAS-9M Probe screened* from 16 to 19 feet bgs.

- **Anderson Landfill – 3 probes**
  GM-2D Probe screened* from 85 to 89 feet bgs.
  GM-6D Probe screened* from 67 to 75 feet bgs.
  GM-11IS Probe screened* from 39 to 45 feet bgs.

- **Benton/Redding Landfill – 2 probes**
  GM-2A-Deep Probe screened* from 22 to 30 feet bgs.
  GM-4A-Deep Probe screened* from 53 to 63 feet bgs.

- **Buena Vista Landfill – 4 probes**
  GP-12M Probe screened Work on symposium handouts (per borescope review) from 38 to 43 feet bgs.
  GP-11D Probe screened* at undetermined depth greater than 40 feet bgs.
  GP-15M Probe screened (per borescope review) from 37 to 53 feet bgs.
  GP-15D Probe screened (per borescope review) from 63 to 83 feet bgs.

- **Crazy Horse Landfill – 1 probe**
  GW-7M Probe screened (per borescope review) from 37 to 47 feet bgs.

- **Azusa Landfill – 1 probe**
  NP1_A Probe screened* from 51 to 56 feet bgs.

- **Bradley Landfill – 1 probe**
  W-2B Probe screened* from 43 to 65 feet bgs.

- **Coyote Canyon Landfill – 6 probes**
  P-45 L3 Probe screened* from 48 to 66 feet bgs.
  P-48 L3 Probe screened from 46 to 61 feet bgs.
  P-48 L4 Probe screened from 70 to 75 feet bgs.
  P-57 L3 Probe screened* from 55 to 70 feet bgs.
  P-61 L3 Probe screened* from 47 to 64 feet bgs.
  P-61 L4 Probe screened* from 72 to 89 feet bgs.

- **City of Huntington Beach Landfill – 1 probe**
  GP-2B Probe screened* from 30 to 50 feet bgs.

- **Milliken Landfill – 1 probe**
  MPG-51S Probe screened (per borescope review) from 10 to 28 feet bgs.

- **Olinda Alpha Landfill – 4 probes**
  MP-6A_1 Probe screened* from 9 to 44 feet bgs.
  MP-5_2 Probe screened* from 21 to 39 feet bgs.
  MP-5_3 Probe screened from 47 to 79 feet bgs.

MP-4_1	Probe screened* from 56 to 99 feet bgs.

- **Otay Landfill – 10 probes**

GP-16 M	Probe screened* from 17 to 28 feet bgs.
GP-16 D	Probe screened* from 35 to 50 feet bgs.
GP-19 M	Probe screened* from 17 to 88 feet bgs.
GP-19 D	Probe screened* from 95 to 170 feet bgs.
GP-9 M	Probe screened* from 17 to 51 feet bgs.
GP-9 D	Probe screened* from 53 to 96 feet bgs.
GP-7 M	Probe screened* from 17 to 48 feet bgs.
GP-7 D	Probe screened* from 55 to 91 feet bgs.
GP-1 M	Probe screened* from 17 to 42 feet bgs.
GP-1 D	Probe screened* from 49 to 75 feet bgs.

- **South Chollas Landfill – 2 probes**

SC-18 D	Probe screened* from 20 to 30 feet bgs.
SC-19 D	Probe screened* from 20 to 30 feet bgs.

* Indicates data obtained from installation records for probe.

With the possible exception of the Otay Landfill†, the 37 probes listed above are considered suspect due to the presence of ambient oxygen in the probe. These probes are considered “suspect” since only one of the several evaluation factors used in this study failed. Note that additional evaluation (see other sections) is necessary prior to the determination that these probes are non-functional.

Depth Trend Analysis

As part of the evaluation of gas data, where available, SCS also reviewed shallow to deep gas trends, particularly CO_2 and O_2 between shallower and deeper probes within the same well in order to further evaluate the validity of the gas monitoring data. Out of a total of 75 wells in the study with at least one shallow and one deeper probe, 39 of the wells had a decreasing oxygen (and increasing CO_2) trend with depth, whereas 20 of the wells had increasing oxygen trends with depth. The remaining 16 wells either had little to no change in oxygen concentrations between probes, or were triple nested, and had mixed trend results. The 21 wells identified with an increase of oxygen with depth are listed on a site-by-site basis and are discussed in more detail below.

† The ambient readings from the Otay Landfill are considered a possible exception since all probes from this site showed ambient oxygen levels, at all depths, which indicates that site lithology may play a significant role in atmospheric intrusion.

- **Anderson Landfill – 3 wells**

  GM-1 — This well had an increase in O_2 between the mid-depth and deep probe (0 percent to 14.7 percent). This is likely due to the decrease in methane between the two probes (17.3 percent to 6.4 percent, respectively) and is thus should still be considered as a functional well.

  GM-2 — This well had an increase in O_2 between the mid-depth and deep probe (0 percent to 20.2 percent). Similar to GM-1, this well also shows a significant decrease in methane between the mid-depth and deep probes (53.3 percent to 0 percent). In addition, CO_2 dropped from 37.6 to 0 percent . This drop, combined with the ambient O_2 levels identified in a deeper probe, is suspect.

  GM-6 — This well had an increase in O_2 between the mid-depth and deep probe (17.6 percent to 20.2 percent). Similar to GM-2, CO_2 levels in this well went from 1.6 percent down to 0 percent. This drop, combined with the ambient O_2 levels identified in a deeper probe, is suspect.

- **Benton/Redding Landfill – 2 wells**

  GM-2A — This well had an increase in O_2 between the mid-depth and deep probe (18.8 percent to 20.0 percent), as well as a drop in CO_2 (1.4 percent to 0 percent). This drop, combined with the ambient O_2 levels identified in a deeper probe, is suspect.

  GM-4A — This well had an increase in O_2 between the mid-depth and deep probe (18.1 percent to 20.0 percent), as well as a drop in CO_2 (0.6 percent to 0 percent). This drop, combined with the ambient O_2 levels identified in a deeper probe, is suspect.

- **Buena Vista Landfill – 1 well**

  GP-11 — This well had an increase in O_2 between the shallow and deep probe (19.7 percent to 20.3 percent), as well as a drop in CO_2 (1.2 percent to 0 percent). This drop, combined with the ambient O_2 levels identified in a significantly deeper probe, is suspect.

- **Clovis Landfill – 3 wells**

  MMW-112 — This well had an increase in O_2 between the 55-foot deep and 65 foot deep probe (5.9 percent to 19.4 percent), as well as a drop in CO_2 (21.6 percent to 0 percent). This drop, combined with the near-ambient O_2 levels identified in a similar depth probe, is suspect.

  MMW-116 — This well had an increase in O_2 between the mid-depth and deep probe (19.5 percent to 19.9 percent). Note there was no CO_2 detected in either probe. The increase in O_2 with depth could easily be attributable to instrument read error due to the closeness of the readings. Therefore, these probes may still be considered functional.

  MMW-122 — This well had an increase in O_2 between the mid-depth and deep probe (4.7 percent to 18.0 percent), as well as a drop in CO_2 (21.9 percent to 2.5 percent). This drop, combined with the increase in O_2 levels identified, while generally considered suspect, may still be indicative of a subsurface environment. Therefore, these probes may still be considered functional.

- **Corral Hollow Landfill – 2 wells**
  GW-3 This well had an increase in O_2 between the mid-depth and deep probe (17.5 percent to 18.4 percent), as well as a drop in CO_2 (3.9 percent to 2.6 percent). This drop, combined with the increase in O_2 levels identified, while generally considered suspect, may still be indicative of a subsurface environment. Therefore, these probes may still be considered functional.
  GW-4 This well had an increase in O_2 between the mid-depth and deep probe (17.5 percent to 19.5 percent), with no CO_2 detected in either probe. This increase in O_2 levels identified, while generally considered suspect, may still be indicative of a subsurface environment. Therefore, these probes may still be considered functional.

- **Crazy Horse Landfill – 1 well**
  GW-8 This well had an increase in O_2 between the mid-depth and deep probe (0.7 percent to 4.5 percent), as well as a drop in CO_2 (16.3 percent to 4.5 percent). This drop, combined with the increase in O_2 levels identified, while generally considered suspect, may still be indicative of a subsurface environment. Therefore, these probes may still be considered functional.

- **Azusa Landfill – 2 wells**
  NP2 This well had an increase in O_2 between the mid-depth and deep probe (19.2 percent to 19.4 percent), as well as a drop in CO_2 (2.8 percent to 2.4 percent). The increase in O_2 with depth (as well as decrease in CO_2) could easily be attributable to instrument read error due to the closeness of the readings. In addition, the levels of O_2 and CO_2 identified may still be indicative of a subsurface environment. Therefore, these probes may still be considered functional.
  NP5 This well had an increase in O_2 between the mid-depth and deep probe (15.1 percent to 17.7 percent), as well as a drop in CO_2 (3.5 percent to 2.4 percent). Although the data trend is opposite what would be expected, the levels of O_2 and CO_2 identified may still be indicative of a subsurface environment. Therefore, these probes may still be considered functional.

- **Coyote Canyon Landfill – 1 well**
  P-61 This well had an increase in O_2 between the mid-depth and deeper probe (20.3 percent to 20.5 percent), as well as a constant CO_2 reading of 0.1 percent. Although the data trend is opposite what would be expected, the levels of O_2 and CO_2 identified may still be indicative of a subsurface environment. Therefore, these probes may still be considered functional.

- **City of Huntington Beach Landfill – 3 wells**
  GP-2 This well had an increase in O_2 between the mid-depth and deep probe (6.6 percent to 20.9 percent), as well as a drop in CO_2 (10.7 percent to 0 percent). This drop, combined with the ambient O_2 levels identified in a deeper probe, is suspect.
  GP-3 This well had an increase in O_2 between the mid-depth and deep probe (10.8 percent to 10.9 percent), as well as a drop in CO_2 (10.2 percent to 9.4 percent). The increase in O_2 with depth (as well as decrease in CO_2) could easily be attributable to instrument read error due to the closeness of the readings. In addition, the levels of O_2 and CO_2 identified may still be

indicative of a subsurface environment. Therefore, these probes may still be considered functional.

GP-5 — This well had an increase in O_2 between the mid-depth and deep probe (7.0 percent to 7.7 percent), as well as a drop in CO_2 (7.0 percent to 6.5 percent). The increase in O_2 with depth (as well as decrease in CO_2) could easily be attributable to instrument read error due to the closeness of the readings. In addition, the levels of O_2 and CO_2 identified may still be indicative of a subsurface environment. Therefore, these probes may still be considered functional.

- **Olinda Alpha Landfill – 2 wells**

  MP-5 — This well had an increase in O_2 between the shallow and deeper probe (20.4 percent to 20.8 percent), as well as a drop in CO_2 (0.7 percent to 0 percent). This drop, combined with the ambient O_2 levels identified in a significantly deeper probe are suspect.

- **Upland Landfill – 1 well**

  MP-6 — This well had an increase in O_2 between the mid-depth and deep probe (8.7 percent to 10.0 percent), as well as a drop in CO_2 (10.1 percent to 7.4 percent). Although the data trend is opposite what would be expected, the levels of O_2 and CO_2 identified may still be indicative of a subsurface environment. Therefore, these probes may still be considered functional.

Methane Concentration

Since most of the probes monitored are considered compliance probes for purposes of perimeter explosive gas control under CCR Title 27 §20921, the concentration of methane identified in these probes is of the utmost importance during monitoring. Typically, a detection of methane in a perimeter probe is indicative of the concentration of methane crossing that monitoring point, headed away from the landfill. In order for a probe to be in compliance with the explosive gas control regulations detailed in §20921, the concentration of methane gas must not exceed 5 percent by volume.

As shown in Table 2 (Appendix B), 12.1 percent (23 out of the 190) of the probes included in this study had a concentration of methane gas greater than 5 percent, deeming them out of compliance with local and state regulations (§20921). While generally the presence of methane above regulatory thresholds is cause for alarm, it should be noted that not all of the probes included in this study are compliance perimeter compliance points, and further, the focus of this study is not enforcement of regulations, but instead the evaluation of the functionality of probes constructed in accordance with them. As such, for the 23 probes that have detections of methane above the regulatory threshold, it can safely be assumed that these probes are, in fact, functional.

Vacuum Testing

Immediately following gas monitoring activities a vacuum test was conducted on each of the probes included in this study. The vacuum test consists of the application of a known vacuum to each probe and noting the change in vacuum (recovery) over time.

In order to complete the vacuum test, a sampling train including a vacuum/pressure gauge, control valve, and vacuum pump was connected to each probe. The probe valve was opened and a vacuum was applied to the probe. The initial vacuum pressure was recorded and the sampling train valve was opened and the residual vacuum was monitored over a 2-minute (120 seconds) period. The residual vacuum decline was noted in 30-second intervals on the Landfill Gas Probe Data Sheet (Appendix B), and is presented in Table 2 (Appendix B). As shown in Table 2, a majority of the probes that were monitored in this study instantly returned to their initial pressure immediately after the vacuum was shut off.

It is generally assumed that any introduced vacuum in a probe without any leaks would drop slowly over time, as gases from the subsurface enter the screened section of the probe. As such, the amount of time necessary for a probe to recover is highly contingent upon the porosity and moisture content of the soils located around the screened section of a probe. For example, a probe with its screened interval in a silty clay would be expected to take longer to recover from the introduction of a vacuum than a probe with its screened interval located in a coarse sand.

Taking all of this into account, it is difficult to precisely determine the nature of the vacuum integrity of a probe. However, as stated above, it is assumed that a probe that decreases in vacuum slowly over time does not have any major leaks in the casing and the wellhead assembly.

It is further assumed that the gas entering the probe after the vacuum was turned off occurs in the screened portion of the casing. However, this may not be the case for all probes. It is difficult to determine from this test if gas is entering the casing in a section other than the screened portion, but based on gas monitoring data and down-casing videos, some ambient air may have entered selected casings due to shallow screened intervals and/or poor seal conditions. Therefore, on its own, vacuum testing is not a fool-proof method of probe functionality determination.

As such, results from the vacuum testing are used in this study to verify probe functionality, as opposed to determining the non-functionality of a probe. For future evaluations, SCS recommends coupling additional gas monitoring post-vacuum testing, in order to assist in determining the nature of the subsurface gases.

Video Borescope Inspection

Each probe monitored during this study was examined with a video borescope in order to visually inspect the integrity of the probe. The video allows us to evaluate the durability and design of the probe, and after review, it aids in the selection of future material selection, construction, and design. Table 2 (Appendix B) shows the results of the video inspection.

After conclusion of the vacuum/pressure test, the well cap was removed from each of the 190 study probes and the video borescope camera was lowered into the probe. First, the probe identification (landfill and probe number) was entered onto the video record. Features such as casing joints, top and bottom of screen, water level (if present), and bottom of probe were identified, as well as any other remarkable features such as casing or screen damage, screens mostly flooded with water, or screens not constructed as designed. At all identifiable features, the depth was recorded on the Landfill Gas Probe Data Sheet. The depth was determined to at least the nearest 0.5 inch by measuring up from the nearest 5-foot marker on the borescope cable.

The primary purpose of the video borescope inspection was the verification of the probe construction information as compared to the installation log and identification of blockages. In addition to the observed depth to the top of the screened interval and bottom of casing depth for each probe, Table 2 also contains information on the top of screen and bottom of casing as obtained from a review of well installation logs.

In addition, Table 2 also contains the calculation of the differential values between the measured versus reported (on the installation log) depth of the screen and the bottom of the casing. In assessing the differences between the installation log and the borescope, it is important to remember that there may be a differential between the probe log and the borescope record based on the fact that the borescope records are reported from the top of the probe casing, whereas probe installation records are typically reported from ground surface. During evaluation of video borescope records, a difference of up to approximately 4 feet was attributed to this variance and was not considered significant for purposes of functionality determination. However, the differences in screen sizes from video log to construction log are still applicable.

Probe Construction Observations

One of the primary goals for the video borescope inspection was the verification of the probe construction logs. As shown in the video still image excerpt presented below, the screened section of a probe was easily detectable using the video borescope.

View of probe screened section
(Coyote Canyon Landfill P-45 L3)

In addition to screened intervals, the overall probe construction could be determined through a review of the video borescope records. For example, in the still image excerpts presented below, it was easy to determine instances where probes were constructed by screwing together PVC sections. Below are pictures of probes with screws used for connecting casing segments.

Screw near bottom of casing,
Anderson Landfill

Screws near joint,
Ukiah Landfill

Screw near joint,
Benton Landfill

While the use of screws as a media to combine pipe segments is not uncommon on landfill sites, it is unclear whether or not they allow air to come through the voids between the screw and the casing. Note that current regulations do not specify the detailed construction of individual probes. Probes with this type of construction do not allow for video borescope inspection. As such, probes with this construction were deemed non-applicable for this study, as designated in Table 2. In addition, probes with a minimal (<2 feet in length) screened section were also considered non-functional.

Probe Obstructions

In almost all of the videos of the probes, one can readily determine the presence/extent of the slotted or perforated section of the probe. However, there were several probes where the bottom of the probe or the screened or perforated section of the probe could not be reached, typically due to some type of obstruction. The obstructions observed in the probes include bentonite, nails, roots, rubber stoppers, bent/collapsed casings, PVC pipe, and soil. Examples are shown in the pictures below taken from the videos.

Soil in casing at
South Miramar Landfill

Rubber stopper at
Buena Vista Landfill

Nail through casing,
South Chollas Landfill

Roots in casing,
South Chollas Landfill

Other notable items were found down the casings of some of the probes monitored in this study. These included salamanders, spiders, centipedes, earwigs, slugs, a bailer, and a data sheet from a consulting firm. Below are pictures of these items taken from the borescope videos.

Salamander at
Ukiah Landfill

Centipede at
Ukiah Landfill

Sampling data sheet at
Red Bluff Landfill

In general, minor obstructions, such as rootlets, may still allow gas to travel in the probe between the screened interval and the probhead for sampling. However, several other types of obstructions (soil, bentonite, stoppers, etc.) will likely retard, if not stop, the flow of gases through the probe. For this reason, SCS identified probes with significant obstructions (clogged with bentonite, soil, flooded with water, etc.) as non-functional.

Wellhead Repair

Following completion of the probe assessment, the gas probes were re-capped with the original probehead assembly. None of the probes monitored in this study had to have the original cap cut off in order to monitor the probe.

Lithology Evaluation

Following completion of the field study, the verified screened interval data obtained from the video inspections was compared to available lithologic logs from probe construction. This was done in order to determine if the probe screened intervals were placed, "preferentially adjacent to soils which are most conducive to gas flow," §20925(c)(1)(D).

The lithology of the screened section for each probe is listed in Table 2 (Appendix B). As shown in Table 2, in general the probes at each landfill site are located in course-grained lithologies. Where probes are located in finer-grained lithologies, it appears that no more coarse-grained lithologies were located above or below the screened interval.

However, based on review of the completion depths for the various probes at the various landfills, it is evident that the vast majority of probes were installed at pre-determined depths, due to the similar depth ranges encountered on a per-site basis. It appears that little, if any, attention was paid to the lithology around the installed screened section.

Probe Functionality Determination

As previously indicated in the Section 3, there is no single way in which to evaluate the functionality of a probe. It is through a combination of observations that probe functionality can be determined. For each probe evaluated under this study, SCS reviewed the results from the various components of the sampling program and made a determination as to the probe's functionality for compliance monitoring purposes. The results of this assessment are provided on Table 2.

As shown in Table 2 (Appendix B), there were a total of 61 probes identified as non-functional, 12 probes identified as "indeterminate," and 117 probes identified as functional. Additional detail on the non-functional as well as probes of indeterminate functionality is presented below.

Non-Functional Probes

As shown in Table 2, a total of 32.1 percent (61 out of 190) of the probes in this study probes were determined to be non-functional. As shown in Table 2, the reasons for non-functionality range from clogged probes to complete lack of a screened section. In addition, it should be noted that some, although not all, of the probes identified as non-functional may be repaired (new probehead assembly, etc.) in order to make the probe functional in the future. A discussion of each of these probes, listed on a site-by-site basis, is presented below:

- **Ukiah Landfill**
  - GAS-9D: Probe flooded‡ at approximately 26 feet bgs (above the observed top of screen).
  - GAS-10M: Probe clogged with soil in the middle of its screened section.
  - GAS-10D: Probe flooded at approximately 20 feet bgs (above the observed top of screen).
- **Anderson Landfill**
  - GM-2D: Probe had a minimal (<2 foot) screened interval and ambient oxygen levels with depth.
  - GM-7M: Probe flooded at approximately 49 feet bgs (2 feet below the observed top of screen).

‡ A "flooded" probe is defined as a probe with greater than 25 percent of screened interval covered in water.

GM-11M	Probe flooded at approximately 61 feet bgs (1 foot below the observed top of screen).

- **Benton/Redding Landfill**

GM-13D	Probe flooded at approximately 43 feet bgs (six inches below the observed top of screen).
GM-1	Probe had a significant (>10-foot) variation from its construction records.
GM-2D	Probe flooded at approximately 16 feet bgs (above the observed top of screen).
GM-2A Deep	Probe flooded at approximately 18 feet bgs (above the observed top of screen).
GM-4A Mid	Probe had a minimal (<2-foot) screened interval.
GM-4A Deep	Probe flooded at approximately 54 feet bgs (above the observed top of screen).

- **Buena Vista Landfill**

GP-11S	Probe utilizes a rubber stopper as a wellhead valve.
GP-11M	Probe utilizes a rubber stopper as a wellhead valve.

- **Clovis Landfill**

MMW-108M	Probe had a minimal (<2-foot) screened interval.
MMW-108D	Probe had a minimal (<2-foot) screened interval.
MMW-112,55	Probe utilizes a bicycle valve as a wellhead valve.
MMW-112,65	Probe utilizes a bicycle valve as a wellhead valve.
MMW-116M	Probe has an obstruction above the screened interval and ambient air in the probe casing.
MMW-116D	Probe is flooded at approximately 60 feet bgs (above the screened interval).

- **Corral Hollow Landfill**

GW-1D	Probe flooded at approximately 67 feet bgs (above the screened interval).
GW-4D	Obstruction observed above the screened interval.

- **Crazy Horse Landfill**

GW-2D	Probe flooded at approximately 40 feet bgs (above the screened interval).

- **Hillside Landfill**

P-18D	Probe had a minimal (<2-foot) screened interval.

- **Kiefer Road Landfill**

GP-40M	Probe had no observed screened section.
GP-44M	Probe had no observed screened section.
GP-42M	Screened section of this probe is covered with a pipe.

- **Azusa Landfill**

NP1_A	Missing sampling cap. Probe open to environment.
NP2_A	Missing sampling cap. Probe open to environment.
NP3_A	Missing sampling cap. Probe open to environment.
NP5_A	Missing sampling cap. Probe open to environment.
NP10_A	Missing sampling cap. Probe open to environment.
NP11_B	Missing sampling cap and blocked at 12 feet bgs (above top of screened section).

- **Bradley Landfill**

W-2B	Probe blocked at a shallow depth with ambient air in the casing.
W-4	Probe had a significant (>10-foot) variation from its construction records.
W-5S	Probe had a significant (>10-foot) variation from its construction records.
W-5M	Probe was blocked at 72 feet bgs (within screened section of probe).
W-6	Probe was blocked at 48 feet bgs (above top of screened section).
W-9B	Probe was blocked at 65 feet bgs (near top of screened section).
W-13	Probe flooded at approximately 5 feet bgs (above the screened interval).

- **Coyote Canyon Landfill**

P-48 L3	Probe flooded at approximately 47 feet bgs (near top of screened interval).
P-48 L4	Probe flooded at approximately 58 feet bgs (above the screened interval).
P-57 L3	Probe flooded at approximately 36 feet bgs (above the screened interval).
P-57 L4	Probe flooded at approximately 45 feet bgs (above the screened interval).
P-61 L3	Probe flooded at approximately 32 feet bgs (above the screened interval).
P-61 L4	Probe flooded at approximately 46 feet bgs (above the screened interval).

- **City of Huntington Beach Landfill**

GP-2B	Probe has ambient levels of O_2 at depth, whereas other probes on-site do not.

- **Milliken Landfill**

MLPO400-D	Probe had a significant (>10-foot) variation from its construction records.

- **South Miramar Landfill**

MW7SM-D	Probe had a significant (>10-foot) variation from its construction records.
MW8SM-D	Probe had a significant (>10-foot) variation from its construction records.
MW10SM-D	Probe blocked at 26 feet bgs (no screened section observed).
MW11SM-D	Probe blocked at 9 feet bgs (no screened section observed).
MW5SM-D	Probe had a significant (>10-foot) variation from its construction records.
MW4SM-D	Probe had a significant (>10-foot) variation from its construction records.
MW3SM-D	Probe blocked after the reported depth of the bottom of casing and therefore had a significant (>10-foot) variation from its construction records.
MW2SM-D	Probe had a significant (>10-foot) variation from its construction records.

- **Olinda Alpha Landfill**

MP-6A_1	Probe had a significant (>10-foot) variation from its construction records.
MP-4_2	Probe had a bentonite blockage within the probe casing at 57 feet bgs (near the top of the screened interval).

- **Otay Landfill**

GP-1D	Probe flooded at approximately 51 feet bgs (above the screened interval).

- **South Chollas Landfill**

SC-18D	Probe had ambient O_2 levels in probe casing, unlike other probes at site of same depth.
SC-19D	Probe had ambient O_2 levels in probe casing, unlike other probes at site of same depth.

Probes of Indeterminate Functionality

In addition to the 61 probes which were determined to be non-functional for compliance monitoring purposes, there were approximately 12 additional probes whose functionality was uncertain based on existing data, and were thus labeled with a status of "Indeterminate" in Table 2 (Appendix B). These typically include probes whose construction records vary slightly (more than 5 feet but typically less than 10) from the borescope records, probes with near-ambient concentrations of O_2, etc. Each of the indeterminate status probes are listed below, along with a recommendation of additional steps to be taken to determine their functionality in accordance with the methodology presented in this study.

- **Anderson Landfill**

  GM-2M — Probe had a slight variation between construction logs and video borescope records. In order to ensure that this probe is properly screened, SCS recommends reviewing the construction logs for the shallow nested probe in this configuration.

- **Buena Vista Landfill**

  GP-12M — Probe had an obstruction at 38.5 feet bgs and near-ambient readings at depth. SCS recommends review of historic sampling data, as well as potentially resampling this probe in order to verify the detected readings. In addition, a review of the construction and lithology logs for this site would be helpful in order to determine if the probe is screened in the proper lithologic layer.

  GP-12D — Similar to GP-12M, SCS recommends remonitoring, review of historical records, and review of the construction and lithology logs for this probe to determine if the probe is screened in the proper lithologic layer due to near-ambient O_2 levels detected in this probe.

  GP-15M — SCS recommends remonitoring, review of historical records, and review of the construction and lithology logs for this probe to determine if the probe is screened in the proper lithologic layer due to near-ambient O_2 levels detected in this probe.

  GP-15D — SCS recommends remonitoring, review of historical records, and review of the construction and lithology logs for this probe to determine if the probe is screened in the proper lithologic layer due to near-ambient O_2 levels detected in this probe.

  GP-10D — SCS recommends review of the construction and lithology logs for this probe to determine the depth of the screened section, since a rubber stopper blocked the video borescope.

- **Hillside Landfill**

  P-17D — SCS recommends remonitoring, review of historical records, and review of the construction and lithology logs for this probe to determine if the probe is screened in the proper lithologic layer due to near-ambient O_2 levels detected in this probe.

- **Milliken Landfill**

  MPG-51S — SCS recommends review of lithology logs for this probe to determine if the probe is screened in the proper lithologic layer.

  MPG-51D — SCS recommends review of lithology logs for this probe to determine if the probe is screened in the proper lithologic layer.

- **Olinda Alpha Landfill**

MP-6A_2	Due to near-ambient O_2 levels and near instantaneous vacuum recovery, SCS recommends remonitoring and review of historical monitoring data in order to determine if the near-ambient O_2 readings in this probe at depth are valid.
MP-5_2	Due to near-ambient O_2 levels and near instantaneous vacuum recovery, SCS recommends remonitoring and review of historical monitoring data in order to determine if the near-ambient O_2 readings in this probe at depth are valid.
MP-5_3	Due to near-ambient O_2 levels and near instantaneous vacuum recovery, SCS recommends remonitoring and review of historical monitoring data in order to determine if the near-ambient O_2 readings in this probe at depth are valid.

Conclusions and Recommendations

Conclusions

Probe Identification

Our overall opinion is that the method of identification used at the study landfills is satisfactory. Of the 190 probes monitored in this study, only 25 were not properly labeled. Of those 25 probes, only four were mislabeled. The other probes did not have any method of identification on them to differentiate the probe depths. In order to interpret monitoring probe data, it is essential that the field representative is monitoring the intended probe at the correct depth, and the only way to identify the correct probe to monitor is by using a proper labeling system.

Surface Emissions

Surface emission monitoring conducted under this study generally indicated that landfill gas was not leaking out of probe casings and into surface soil. This conclusion is based upon the gas concentration and surface emission data contained in Table 2 (Appendix B). With few exceptions, all of the probes that contained concentrations of landfill gas in the probe casing did not have any surface emissions around the probe.

Significant surface emissions were detected around well GW-1 (containing probes GW1S, GW-1M, and GW-1D) at Crazy Horse Landfill. The reason for these surface emission detections was likely due to the significant methane concentrations (10 percent by volume) identified within the well box. The well box likely had such significant concentrations due to the observation that one of the probes having been left open within the box, thus allowing LFG to migrate to the surface.

Probe Construction

All of the probes that were investigated in this study were constructed of PVC piping with a perforated or screened interval. Most of the probes were constructed using 10-foot sections of piping, with few exceptions. At Buena Vista Landfill, a few probes were constructed with five-foot sections of pipe. This doubles the number of joints on the probe, which could increase the possibility of leaks. By constructing probes with longer pipe segments, the possibility of biofouling (blockage by organic material such as roots) and blockages by bentonite and dirt is decreased.

A few probes that were monitored had screws used as a binding material for overlapping pipe segments. This procedure should probably be avoided in order to allow future access for visual inspections. Most of the probes that were monitored were constructed with threaded couplings and o-rings rather than slip couplings and screws. It is recommended that threaded coupling be used in order to minimize the possibility of gas intrusion.

Most of the wellhead assemblies on the probes were designed to function properly, with a few exceptions. A wellhead assembly should include at minimum a locking valve with a sampling port. Wellhead assemblies that did not meet this specification used rubber stoppers (Buena Vista Landfill). Other valves that closed, but could not be opened without proper equipment, were the bicycle valves at Clovis Landfill, Quick Disconnects at Bradley, Hillside, and Crazy Horse landfills, and the sampling tube at Azusa Landfill.

The selection of probe locations, in terms of depth and topography, is crucial in the planning process. Probes that were located close to vegetation had some degree of root intrusion either in the screened interval or between the joints of the probe. Roots can destroy probes by cracking the casing, rendering them useless, and one would not know a probe was cracked unless a video borescope was sent down to investigate. In order to minimize the possibility of root intrusion on a probe, the probe location should be placed as far away from vegetation, if possible, or should be periodically inspected and cleared of vegetation.

The depth of the probe in relation to the water table is also a crucial step in the planning process in order to prolong the life of the probe. Many of the probes monitored in this study extended past the water table, and in some cases, the whole screened interval of the probe was submerged, deeming the probe useless. In order to maximize the effectiveness of the monitoring probe, the depth to the water table plus seasonal fluctuations in the water table should be taken into account when determining the depth of the probe.

In addition, as indicated previously, more rigor should be applied in consideration of soil lithology and the location of a screened interval of a compliance probe. The specified depths of the monitoring probes within the wellbore should be installed based on the most permeable lithology encountered, in accordance with §20925(c)(1)(D).

Durability of Materials

The materials used at the study landfills are adequate in maintaining their integrity over time with few exceptions. A slip cap that held the quick disconnect valve on a probes at Hillside Landfill had a crack, which was probably from a combination of heat and stress. A probe at Clovis Landfill had stripped threading where the valve was connected to the probe. A probe at Crazy Horse Landfill was broken about 1.5 feet below the ground surface, which was probably due to an accident.

Overall, the remainder of the probes monitored did not have any problems with the durability of the materials (degradation of PVC, etc.).

Statewide Probe Functionality

Based upon this study, the current approach to LFG perimeter migration monitoring probe design, construction, and installation is unsatisfactory. An industry/regulatory standard should be set for probe construction and installation. Recommendations that may extend the lifespan of monitoring probes and provide for a higher level of confidence in detecting migrating LFG are discussed below.

Recommendations

Based upon the findings, SCS Engineers recommends that CCR Title 27 §20925 be modified to include the following:

1. Probes should be constructed with longer screened segments (as opposed to shorter, and such that screened sections do not overlap). A longer screened section reduces the possibility of blockages by bentonite, as well as the presence of dirt and roots.
2. Wherever possible, probes should be assembled using threaded coupling, as opposed to slip coupling and/or screwed together joints, or glued/solvent welded. This will ensure that gas samples are collected from the screened interval of a probe as opposed to areas where casing might leak due to a bad seal and/or screwed-together joints. SCS understands that some portions of a probe (e.g., endcap and wellhead) cannot be preconstructed and thus, may require a slip-type fitting.
3. All probes should be constructed using a non-proprietary locking valve on the probehead assembly (labcock valve, quick connect valve, or similar). This will ensure that valid pressure readings can be obtained from the probe from on-site personnel as well as regulatory agencies.
4. Probes should be preferentially located as far away from surface vegetation as possible in order to avoid root intrusion into shallow probes.
5. Development of a standard probe specification and construction criteria.
6. Require professional geologist/engineer certification of installed/completed probes, including rationale for preferential placement of mid-depth probe(s) based on lithology.
7. Periodic functionality assessments should be initiated for all probes at every landfill site. One recommended implementation would be to perform a functionality assessment every ten years (following initial probe installation). The ten-year term is based on the average age of the probes evaluated in this study, which ranged from under five years to more than 25 years.

Appendix A
November 2006 Work Plan

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WORK PLAN FOR

ASSESSMENT OF LANDFILL GAS

MONITORING WELL VIABILITY AT

TWENTY CALIFORNIA LANDFILLS

Prepared For:

California Integrated Waste Management Board

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Contract: IWM-05102

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November 2006

This Work Plan for the Assessment of Landfill Gas Monitoring Well Viability at Twenty California Landfills, dated November 2006, was prepared and reviewed by the following:

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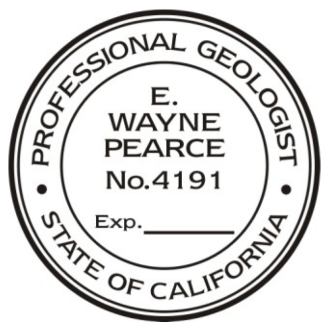

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SCS ENGINEERS

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WORK PLAN FOR

ASSESSMENT OF LANDFILL GAS

MONITORING WELL VIABILITY AT

TWENTY CALIFORNIA LANDFILLS

INTRODUCTION AND OBJECTIVES

The California Integrated Waste Management Board (CIWMB) has retained SCS Engineers (SCS) to conduct a study of existing landfill gas (LFG) monitoring wells (probes) located at 20 landfills throughout the State. The intent of the study is to determine if the existing gas probes have been designed, constructed, and are functioning properly and are capable of detecting lateral migration of landfill gas. If it is shown that a significant number of gas probes are not functioning properly due to inadequate design, improper installation, normal deterioration, subsurface changes or vandalism, landfill gas migrations may be underestimated or undetected, potentially leading to dangerous conditions for persons and facilities located near landfills and to adverse effects on the environment. Also, the amount of landfill gas being generated and released from landfills may be underestimated and models for emission of greenhouse gasses (GHG) may need to be revised. Finally, depending on the results of the study, existing regulations may need to be modified to ensure that gas probes installed around landfills are functional and capable of detecting migrating landfill gas, if present.

The assessment of landfill gas monitoring well viability to be completed under this study will focus on visual and physical testing of 200 landfill gas probes located at 20 sites in California. This work plan presents the methods that will be used to accomplish this study.

PROJECT OBJECTIVES AND APPROACH

CIWMB has selected 20 landfill sites in northern and southern California to be included in this study. The landfills were selected to include a variety of landfill sizes, geomorphic and geologic settings, and the presence of relatively deep gas probes (40-100 feet). These deeper probes have the greatest potential for installation problems, ground water infiltration, or other conditions that could render them ineffective monitoring points. Table 1 presents a listing of the landfills to be included in the study.

SCS reviewed internal files regarding the sites selected by CIWMB to determine if landfill gas probe information existed, for these sites, in the SCS files. Data of concern included:

- Locations of probes;

- Construction details and as-built diagrams;
- Completion depths;
- Gas monitoring history; and
- Site geology.

Table 1.

Landfills Selected for Study

	Landfill Name	County	City	SWIS#
Northern CA Sites	Clovis	Fresno	Clovis	10-AA-0004
	Ukiah	Mendocino	Ukiah	23-AA-0019
	Crazy Horse	Monterey	Salinas	27-AA-0007
	Kiefer	Sacramento	Sloughhouse	34-AA-0001
	Coral Hollow	San Joaquin	Tracy	39-AA-0005
	Hillside	San Mateo	Colma	41-AA-0008
	Buena Vista	Santa Cruz	Watsonville	44-AA-0004
	Anderson	Shasta	Anderson	45-AA-0020
	Redding/Benton	Shasta	Redding	45-AA-0019
	Red Bluff	Tehama	Red Bluff	52-AA-0001
Southern CA Sites	Azusa	Los Angeles	Azusa	19-AA-0013
	Bradley	Los Angeles	Sun Valley	19-AR-0008
	HB Sports Complex	Orange	Huntington Beach	30-AB-0026
	Olinda Alpha	Orange	Brea	30-AB-0035
	Coyote Canyon	Orange	Newport Beach	30-AB-0017
	Upland	San Bernardino	Upland	36-AA-0005
	Milliken	San Bernardino	Ontario	36-AA-0054
	South Chollas	San Diego	San Diego	37-AA-0022
	South Miramar	San Diego	San Diego	37-AA-0033
	Otay Landfill	San Diego	Chula Vista	37-AA-0010

After obtaining as much data as possible from the SCS files, a data request was made to CIWMB for missing data. This included those sites for which SCS did not have any data, or for portions of data not in our files.

The actual probes to be investigated at each landfill will be selected by CIWMB staff, at each site, on the day or days of each site study.

SAMPLING PROGRAM

SCS will accomplish the landfill gas probe viability testing through a standardized approach to be applied at all 20 landfills and 200 gas probes. All data collected for each probe investigation will be recorded on a Landfill Gas Probe Field Data Sheet.

Selection of Gas Probes

CIWMB staff will select the probes to be investigated at each landfill. The probes to be studied will be selected upon arrival at each site.

3.2 Notification and On-Site Arrival

Prior to the planned arrival date for each landfill, the CIWMB will contact the landfill operator to let them know when Board and SCS staff are planning to be on-site. If the owner/operator wishes to have a representative present during the probe study, arrangements will be made to accommodate the representative.

Ambient Conditions

For each gas probe to be studied, SCS will first record ambient conditions including atmospheric conditions, barometric pressure, temperature, wind speed and direction. These will be recorded on the Landfill Gas Probe Field Data Sheet.

Surface Conditions

For each gas probe to be studied, SCS will verify the probe identification to determine if it is properly labeled and properly located on site maps. SCS will then digitally photograph the gas probe wellhead and surrounding area. Alternatively, the wellhead and surrounding area may be recorded on a video recorder. Photograph or video identification (picture number, etc.) will be recorded on the Landfill Gas Probe Field Data Sheet.

A scan will be made of the surface, in a 5-foot radius around each probe, using an RKI Eagle to measure methane emissions. If no emissions are detected, this will be recorded on the Landfill Gas Probe Field Data Sheet. If methane emissions are detected, the concentration and location will be recorded on the Landfill Gas Probe Field Data Sheet.

Probe Gas Monitoring

Before the gas probes are opened for inspection, SCS will determine gas concentrations and pressure in each probe. This will be done for methane, carbon dioxide, oxygen, carbon monoxide, and hydrogen sulfide. These readings will be collected using GEM 2000 and RKI Eagle instruments. Readings will be monitored until a steady state level has been achieved for 30 seconds (if possible). Gas concentrations observed will be recorded on the Landfill Gas Probe Field Data Sheet.

Pressure Integrity Test

The pressure integrity test consists of the application of vacuum to each probe and noting the change in vacuum over time. The integrity test will be conducted immediately following the gas monitoring activities.

Following gas monitoring activities (Section 3.5, above), the probe valve will be closed prior to turning off and/or disconnecting the GEM2000 from the probe. A sampling train including a vacuum/pressure gauge, control valve, and vacuum pump will then be connected to each probe. The probe valve will then be opened and a negative pressure suitable for the purpose will be applied. The initial vacuum pressure will be recorded on the Landfill Gas Probe Field Data Sheet. After applying the vacuum, the sampling train valve will be closed and the residual vacuum monitored. The rate of residual vacuum decline will be noted on the Landfill Gas Probe Data Sheet.

Video Borescope Inspection

After conclusion of the vacuum/pressure test, the well cap will be removed from each of the 200 study probes and the video borescope camera will be lowered into the probe. First, the probe identification (landfill and probe number) will be entered onto the video record. Then, as the camera is lowered, each 5-foot marker on the borescope will be entered via keyboard onto the video record of the probe. Features such as casing joints, top and bottom of screen, water level (if present), and bottom of probe will be identified on the video record, as well as any other remarkable features such as casing or screen damage or screens not constructed as designed. At all identifiable features, the depth will be entered onto the video record via keyboard. The depth will be determined to at least the nearest 1/10th of a foot by measuring up from the nearest 5-foot marker on the probe.

The video record for each probe will be recorded onto either temporary storage media (Compact Flash Cards) and later transferred to a computer hard drive, or recorded directly to a mass storage hard drive.

Wellhead Repair

Following completion of the video borescope inspection, the gas probes will be re-capped with the original PVC cap or, if the original cap had to be cut off, replaced with a similar well cap. To the extent possible, the well cap will be configured with the same sampling port as the original.

DATA EVALUATION AND REPORTING

Comparison of Field Data to Records

Following completion of each landfill field data collection, data obtained from the video inspections will be compared to the records available for the probes. This will include comparison of construction features and installation depths to as-built drawings and/or well logs. Probe locations will be compared to available maps to determine if the probes are properly located and identified.

Preparation of Well Viability Report

SCS will prepare a Gas Well Viability Report based on the observations noted during the field work, video borescope records, and existing data on the probes. The report will list, on a probe by probe basis, the results obtained and whether each probe is considered viable as a gas monitoring point. Landfill Gas Probe Field Data Sheets for all probes will be included in the report as an appendix. The report will also contain video records of the video borescope inspections on either CD or DVD disks, which are on file with CIWMB.

Using these results, SCS will draw conclusions on all aspects of probe functionality taking into account construction problems, durability of materials, changes in subsurface conditions like blockage by ground water, vandalism, and in addition, considering the possibility of errors related to probe miss-identification. SCS will also make recommendations regarding the overall approach to installation of gas probes and draw conclusions as to statewide probe functionality as the sole means for detection of landfill gas migration at landfills.

Preparation of Greenhouse Gas Emissions Report

Using the data from the study, SCS will also evaluate how the results of this viability study of LFG monitoring probes can be used to supplement or refine the California Energy Commissions' (CEC's) proposed LFG emissions model.

The integrity of LFG migration probes may present a potential conduit for LFG/methane that is not accounted for in the CEC flux study. The results of our study may suggest that lateral probe migration may be an input parameter to the CEC model or at least be further studied as part of the CEC project. In addition, SCS will evaluate the use of various published models for LFG migration in porous media to assist in the evaluation.

In addition, it should be noted that LFG probes are used as an assessment tool to determine how effective a LFG collection and control system is at controlling subsurface LFG migration. This study will assist in determining whether the data derived from existing probe designs, particularly multi-depth probes, is sufficient to use for this purpose. If so, LFG probe data may be a recommended variable for the CEC's LFG emissions model for determining collection efficiency. If not, our report may recommend that probe data not be used for this purpose.

In our final greenhouse gas emissions report, SCS will summarize this evaluation and provide recommendations as to how we see these data should be used for the CEC project. If feasible, we would recommend modifications to the CEC study or at least the inclusion of additional input variables to the CEC model, which could increase the accuracy of the GHG estimates.

APPENDIX A

QUALITY ASSURANCE/
QUALITY CONTROL PLAN

QUALITY ASSURANCE/QUALITY CONTROL PLAN
CIWMB GAS PROBE VIABILITY STUDY

OBJECTIVE

The objective of the Quality Assurance/Quality Control Plan is to establish standard procedures for the study in order to ensure that data collected at all 20 landfills and all 200 gas probes to be investigated are comparable. The procedures described herein should be followed for all probe investigations. If an unforeseen condition results in an alteration of the procedures, these should be carefully documented.

This study entails field observations and measurements only, followed by preparation of the Gas Probe Viability Report. No samples are to be collected for laboratory analyses. Therefore, the procedures given in this QA/QC Plan are limited to field activities and recording of field data and observations.

SUMMARY OF ACTIVITIES

Activities to be accomplished for this study are described in the Work Plan. For each landfill and each probe to be investigated these include:

1. Arrive at landfill and select probes to be studied (CIWMB staff to select probes).
2. For each probe inspection, record weather conditions.
3. Confirm probe identification and location compared to existing maps and numbering.
4. Inspect and photograph the wellhead and vicinity to document conditions.
5. Scan the surface around each wellhead for methane emissions.
6. Measure ambient pressure/vacuum in the probe.
7. Obtain gas concentration readings.
8. Connect wellhead vacuum test equipment and conduct a vacuum integrity check.
9. Remove the wellhead and perform and record a video borescope inspection of the probe.
10. Complete the probe inspection and replace/rebuild the probe wellhead.

FIELD QA/QC PROCEDURES

A two-person team will be used for the field activities. This is to manage the video borescope equipment, which is best accomplished by two persons, and record filed data and observations. This requires a set system of data recording and communications between personnel. The primary instrument for field data recording will be the Landfill Gas Probe Field Data Sheet. An example data sheet is provided at the end of this Appendix. The data sheet is two-sided and one should be completed for each probe investigated. When completing the Landfill Gas Probe Field Data Sheet, the following procedures should be used:

- Record data using an indelible ink pen.
- Cross out errors with single stroke and record correction (or complete new data sheet).
- When one person is recording data being collected and read aloud by another, the person recording the data should verbally confirm the data back to the originator. This is to confirm that the information was heard and recorded properly.
- One person should principally record the data for each probe investigation. The other person should check the Landfill Gas Probe Field Data Sheet, after completion of each probe investigation, for completeness and accuracy.

After completion of each landfill investigation (10 probes), the Landfill Gas Probe Field Data Sheets should be copied and sent to the Project Manager.

Other field QA/QC procedures involve the proper calibration of the instruments used to record the data. Instrument descriptions, serial numbers, calibrations procedures used, or most recent calibration data (if calibrated by others), will be recorded in the field notes for each landfill investigation.

REPORT QA/QC PROCEDURES

After field investigations have been completed all landfills, data collected will be summarized in the Landfill Gas Probe Viability Report. Field Data Sheets will be included in an Appendix of the report. A draft version of the Report will be reviewed by the SCS field personnel that completed the investigation, and by at least one senior staff member familiar with the project.

APPENDIX B

SAMPLING AND ANALYSIS PLAN

SAMPLING & ANALYSIS PLAN

CIWMB GAS PROBE VIABILITY STUDY

OBJECTIVE

The objective of this Sampling and Analysis Plan (SAP) is to provide a summary of data collection activities to be accomplished. The contents of this SAP mirror the activities described in the Work Plan. Because no samples are being collected for laboratory analysis, the sampling and analysis activities are limited to field observations using real-time instruments and observations. These are addressed in the following Standard Operating Procedure used by SCS Engineers for Landfill Gas Probe Testing.

STANDARD OPERATING PROCEDURE No. 101-rev 0

PERIMETER PROBE MONITORING AND SAMPLING

Revised January 30, 2006

Reviewed and Approved by Mark Beizer- SCS Engineers

1.0 PURPOSE AND SCOPE

In compliance with subparagraph (c)(4)(B) of South Coast Air Quality Management District (SCAQMD) Rule 1150.1, the Stipulated Permanent Injunction, and the Operations Plan (Class I Part B permit), perimeter probes have been installed at specified locations outside the waste disposal areas at the BKK Landfill. This SOP contains procedures for the monitoring and sampling of the perimeter probes.

2.0 RESPONSIBILITIES AND QUALIFICATIONS

The OM&M Task Manager (TM) is responsible for assigning project staff who are qualified to perform the tasks listed in this SOP.

The project staff and subcontractors assigned to perform these operations are responsible for completing their tasks according to this and other appropriate procedures. All staff are responsible for reporting deviations from the procedure or nonconformance to the TM.

Only qualified personnel shall be allowed to perform this procedure. At a minimum, staff qualified to perform these activities will be required to have:

- Read this SOP and corresponding Activity Hazard Analysis
- Signed the attached form to indicate to the TM that all procedures contained in this SOP are understood and will be followed
- Completed the OSHA 40-hour training course and/or 8-hour refresher course, as appropriate
- Previously conducted these operations in a manner generally consistent with the procedures described in this SOP
- A demonstrated ability based on previous experience performing similar activities
- Medical monitoring in accordance with HAZWOPER requirements

Project staff that do not have previous experience performing these operations will be trained onsite by qualified personnel, and will be supervised directly until they have demonstrated an ability to perform the procedures.

3.0 PROCEDURES FOR PROBE MONITORING AND SAMPLING

3.1 PROBE MONITORING AND SAMPLING

3.1.1 Equipment

Personnel conducting perimeter probe monitoring and sampling will require the following equipment.

- LANDTEC GEM-500™ or -2000™
- Magnehelic gauges
- Flame ionization detector
- Tygon tubing
- Calibration Gases
- Sample containers (Tedlar Bags or Stainless Steel Canisters)
- Pen
- Paper / Field Forms (Probe monitoring log, chain-of-custody)
- Latex Gloves
- Safety Glasses
- Steel-toed Boots
- Orange Traffic Vest

The LANDTEC GEM-500™ or -2000™ electronic instrument that is calibrated to measure the concentration of methane, carbon dioxide and oxygen gas, as well as measure static pressure and atmospheric pressure (only the GEM-2000™ can read atmospheric pressure). The LANDTEC GEM-500™ or -2000™ is also equipped with an electric pump that is capable of pumping soil gas at a maximum flow-rate of 300 cubic centimeters per minute (cc/min). The LANDTEC GEM-500™ or -2000™ instrument will be calibrated for methane by manufacturer specifications, using specific concentrations of high-quality calibration gases. The GEM-500™ or -2000™ will be calibrated prior to each day of monitoring and documented on the calibration log.

3.1.2 Procedure [Field crews use an OVA for readings]

Probe testing will be conducted using procedures described in the Rule 1150.1 guidelines. An approved gas extraction monitor (LANDTEC GEM-500™ or -2000™) will be used to measure the volume concentration of total organic compounds (TOCs), expressed as percent of ppm methane. The GEM-500™ or -2000™ instrument is also used to measure the static pressure in the probe and atmospheric pressure prior to monitoring gas composition. All data are recorded and stored in the GEM-500™ or -2000™ at the time of monitoring. Each reading is stored with a date and time stamp. Data are to be uploaded from the GEM-500™ or -2000™ to the SCS database.

Upon arriving at the probe, personnel should perform the following steps:

1. Attach tubing from a Magnehelic gauge. Open the stopcock and measure the pressure in inches of water column.
2. Record the probe identification number, date, time and name of monitoring personnel on the probe monitoring log. For multiple depth probes, confirm the sub-probe identification number or letter and record on the probe monitoring log.
3. Connect an end of a quarter-inch, inner diameter, Tygon tube (approximately a foot in length) to the gas inlet port on the GEM-500™ or -2000™.
4. Connect the opposite end of the Tygon tube onto the soil gas probe's outlet sample port.
5. Open the valve connected to the soil gas probe to channel gas from the soil, through the Tygon tube, to the GEM-500™ or -2000™.
6. Static pressure build-up in the soil is recorded by the GEM-500™ or -2000™.

7. The atmospheric pressure is also recorded by the GEM-2000™ just prior to or immediately after recording the static pressure in the probe.

8. Activate the electric pump on the GEM-500™ or -2000™ and operate until three probe volumes have been pumped out of the probe. An example of the calculation method used to determine the volume to pump out of a soil gas probe is included in Attachment 1.

9. The gas composition (methane, oxygen, carbon dioxide and balance gas at concentration range of 1,000 ppmv to 100 percent by volume) is recorded by the GEM-500™ or -2000™. Lower range measurements are obtained using a flame ionization detector (0 to 1,000 ppmv). If the oxygen level in the probe drops below 16 percent by volume, flame-out of the detector is possible. Use a diluter connected to the tip of the detector to obtain a probe reading.

10. Based on field measurement obtained with the GEM-500™ or -2000™, if the TOC concentration in any of the probes is five percent by volume or greater, one 10-liter bag sample shall be collected from the probe(s) with the highest concentrations above five percent (up to a maximum of five probes). The sample will be taken by connecting a Tygon tubing from the GEM-500™ or -2000™ to the Tedlar bag and operating the electric pump on the GEM-500™ or -2000™ continuously until the bag is filled. If canisters are used to collect the sample, they are pre-evacuated and do not need the GEM pump for filling.

11. If a sample has been taken, record the sample number on the probe monitoring log, on the sample container and complete the chain-of-custody form to accompany the sample to the laboratory.

12. If a field QA/QC sample blank is required by the SAP, label and prepare the sample container and record the sample identification information of the probe monitoring log and the chain-of-custody.

13. If a duplicate sample is required by the SAP, obtain the sample following the procedures in step 9 and 10 above.

14. Close the valves on the probe and/or the sample container then disconnect the Tygon tubing.

15. For probe locations with multiple depth casings, repeat the above procedures.

All collected samples will be submitted to an approved laboratory for analysis of methane, total non-methane hydrocarbons (TNMHCs), and rule 1150.1 core group toxic air contaminants or other testing as may be described in the special investigations.

Probes that have readings of > 1,000 ppmv for 2 consecutive days are classified as “targeted probes”. Targeted probes require an engineering analysis to determine mitigation methods. The engineering analysis will include the following tasks:

- A thorough review of targeted probe and adjacent probe monitoring data.
- Review the geology
- Examine for possible liquid impacts
- Review the influence of nearby gas extraction wells in the area of affected probes
- Review possible barometric pressure effects

- Review the records on system operation for the previous 2 week period.

To help ensure the requirements of the site compliance plan are met, SCS will promptly notify the Working Group if any of the probe GEM-500™ or -2000™ are approaching 1,000 ppm methane by volume. This will enable the Working Group to implement appropriate mitigation measures as soon as possible. SCS will subsequently perform follow-up GEM-500™ or -2000™ monitoring at the affected probe no later than the allowable time after the initial monitoring. Mitigation monitoring results will be documented on the probe monitoring log.

3.1.3 Frequency

The perimeter probes will be monitored quarterly. Probes that exceed 1,000 ppmv for two consecutive days will be classified targeted probes. Targeted probes are measured daily until the gas concentration is less than 1,000 ppmv; once the < 1,000 ppmv value is achieved the probes are monitored weekly and the probe is considered declassified. If a declassified probe has no gas readings exceeding 500 ppmv for a period of three months, the probe monitoring frequency is reduced to monthly. If concentrations remain below 500 ppmv for a period of six months, the probe is reclassified as a quarterly probe.

3.1.4 Quality Control Procedures

After each perimeter probe has been evacuated and measured for TOCs, sample control forms are to be completed detailing the sample container identification number, along with the date and time of sample collection.

Upon the completion of sampling, samples are to be numbered to coincide with probe locations, dated and delivered to the laboratory. All samples will be analyzed within a 72-hour period following collection.

Chain-of-Custody forms are to be completed before the samples are delivered to the laboratory. The chain-of-custody forms will contain an identification number for reference to probe number and location. Sample custody forms are to be released and signed by field staff, and will accompany samples to the laboratory, where they will be signed upon receipt.

4.0 DOCUMENTATION

All data are recorded and stored in the GEM-500™ or -2000™ at the time of monitoring. Each reading is stored with a date and time stamp. Other field readings, (static pressure and flame ionization detector readings) will recorded be on field forms. In the office:

Data are to be uploaded from the GEM-500™ or -2000™ to the SCS database. This program stores each set of probe readings in a site file. The data can be accessed for review by authorized users. Probe monitoring and sampling activities are to be recorded on the probe monitoring log. After each perimeter probe has been evacuated and measured for TOCs, sample control forms are to be completed detailing the sample container identification number, along with the date and time of sample collection. The original probe monitoring logs and sample control forms are to be kept on file at the site.

5.0 MODIFICATIONS TO SOP

This SOP is to be reviewed periodically and no less than once a year to determine if any modifications are required. In the event the SOP needs any changes, those modifications will be discussed with DTSC and will not be implemented until DTSC has approved the revised SOP.

6.0 LIST OF RELATED SOPs

SOP 102 – Landfill Gas Sampling – Extraction Well or Header

APPENDIX C

HEALTH AND SAFETY PLAN

SITE HEALTH AND SAFETY PLAN

LANDFILL GAS PROBE VIABILITY STUDY

SCS JOB #01206102.00

JOB LOCATION: 20 Landfill sites located throughout California. Specific landfills and locations are listed in Table 1.

Table 1.

Landfills Selected for Study

	Landfill Name	County	City	SWIS#
Northern CA Sites	Clovis	Fresno	Clovis	10-AA-0004
	Ukiah	Mendocino	Ukiah	23-AA-0019
	Crazy Horse	Monterey	Salinas	27-AA-0007
	Kiefer	Sacramento	Sloughhouse	34-AA-0001
	Coral Hollow	San Joaquin	Tracy	39-AA-0005
	Hillside	San Mateo	Colma	41-AA-0008
	Buena Vista	Santa Cruz	Watsonville	44-AA-0004
	Anderson	Shasta	Anderson	45-AA-0020
	Redding/Benton	Shasta	Redding	45-AA-0019

	Red Bluff	Tehama	Red Bluff	52-AA-0001
Southern CA Sites	Azusa	Los Angeles	Azusa	19-AA-0013
	Bradley	Los Angeles	Sun Valley	19-AR-0008
	HB Sports Complex	Orange	Huntington Beach	30-AB-0026
	Olinda Alpha	Orange	Brea	30-AB-0035
	Coyote Canyon	Orange	Newport Beach	30-AB-0017
	Upland	San Bernardino	Upland	36-AA-0005
	Milliken	San Bernardino	Ontario	36-AA-0054
	South Chollas	San Diego	San Diego	37-AA-0022
	South Miramar	San Diego	San Diego	37-AA-0033
	Otay Landfill	San Diego	Chula Vista	37-AA-0010

PROJECT DESCRIPTION: The project will consist of the in-field evaluation of 10 landfill gas (LFG) perimeter migration monitoring probes at each landfill site. Activities will include video-logging, probe monitoring, and pressure-testing of each probe in order to determine the probe's integrity and viability in effectively monitoring greenhouse gas migration from the subsurface. Additional detail on the proposed scope of work is presented in the November 2006 workplan, *Work Plan for Assessment of Landfill Gas Monitoring Well Viability at 20 California Landfills*.

ON SITE ORGANIZATION AND COORDINATION:

Project Team Leader:	Wayne Pearce, SCS
Primary Health & Safety Officer:	Ray Huff, SCS
On-Site Safety Officer:	Ryan Farrell/Steve Crowsdale, SCS
Client Representative:	John Bell, CIWMB

CHEMICAL HAZARD EVALUATION: While the proposed workplan does not anticipate encountering raw landfill gas (LFG), a brief listing of some of the priority pollutant chemicals of chief regulatory concern, which may be found in significant (percent-range) levels within raw LFG (specifically methane) is contained on the attached MSDS sheets. Consult National Institute of Occupational Safety and Health (NIOSH) Chemical Hazards Guide for proper precautions to be taken for each constituent (a copy of this guide should be found in each PPE bag issued by SCS). Concentrations of these and other constituents known to exist in LFG will be continuously monitored during all on-site activities.

PHYSICAL HAZARD EVALUATION:

- Landfill gas and subsurface combustion emissions
- Methane gas building up in and below-grade structures and sampling equipment
- Potentially harmful microorganisms in decomposing refuse (if encountered)
- Animals (e.g., rats) and vectors (e.g., mosquitoes).
- Working in proximity to heavy equipment
- Slippery footing on slopes could be present on the landfill.

Proper precautions should be taken to avoid these possible hazards.

NATURAL HAZARDS: The following hazards could be potentially encountered while performing the investigation and assessment functions of the project:

- Sun Exposure- Prolonged exposure to the sun may cause fatigue, headaches, rash and/or sunburns
- Animals- Rodents, poisonous insects, snakes, and/or plants are a natural part of any ecosystem.

SITE SECURITY/SITE CONTROL: A controlled work area will be prepared for the assessment effort. The PVLF is a controlled site, with access only allowed to trained personnel. As such, site security/control efforts will include coordination with LACSD personnel on cordoning off sampling/work areas and access control to on-site structures and vehicles.

MONITORING EQUIPMENT: Continuous monitoring of the breathing zone in the active work area will be conducted using a RKI Eagle. The RKI Eagle has a multi-gas meter capable of monitoring methane (both percent lower explosive limit [LEL] and percent by volume), carbon monoxide (in parts per million [ppm]), hydrogen sulfide (in ppm), and percent oxygen. In addition, a Foxboro Organic Vapor Analyzer (OVA) will also be used on an as-needed basis to evaluate total organic vapors (TOV) as methane present in ambient air in the part per million range.

SCS has established breathing zone action levels, based on the OSHA PELs for various components and the LEL for methane. A summary of the pertinent action levels for this project are summarized on Table 2. In the event that any of the action levels are exceeded in the breathing zone of the active work area for an extended period (more than 5 minutes of continuous monitoring), action will be taken to either address the source of emissions (i.e covering area per project description) or upgrade of personal protective equipment (PPE) from Level D (steel-toed boots, hard-hat, etc.) to levels C (level D PPE + half-facepiece respirator).

However, in the event that unsafe oxygen and/or carbon monoxide levels are encountered in the breathing zone of the active work area, operations in the active work area will cease and the level of PPE required for the project will be reevaluated by the Project Health and Safety Officer.

TABLE 2 – AIR MONITORING ACTION LEVELS

Parameter	Instruments	Action Level
Methane and TOV as Methane	RKI Eagle and Foxboro OVA	At or above 10% LEL (e.g., 5,000 ppm)
Carbon Monoxide	RKI Eagle	Above 50 ppm
Hydrogen Sulfide	RKI Eagle	Above 20 ppm
Oxygen	RKI Eagle	Below 19.5% or above 23.5%

%	Percent gas by volume
% LEL	Percent of the lower explosive limit
ppm	Parts per million

STANDARD PROCEDURES: The following are standard procedures that SCS will follow while on site:

- **No smoking:** Smoking will not be allowed at anytime on site unless designated smoking areas are available.

- **Personal Protective Equipment:** SCS personnel will wear Level D protection in the active work area. Level D protection includes steel-toed work boot, work gloves, hard-hat, eye protection, and high visibility work vest. Additional personal protective equipment for Level C protection will be available in the employee's PPE bag. The PPE bag will be with the employee at all times.

Note: All site employees will conduct work activities in a safe manner at all times. This includes general safe work practices, accident reporting, and health and safety plan review.

FIELD HYGIENE: Avoiding and/or minimizing contact with refuse, contaminated soil, etc. greatly simplifies decontamination and reduces the potential of injury. Skin abrasions, cuts, and scratches enhance potential for infectious agents or chemicals to penetrate the body. Skin injuries should be adequately covered. Washing with antibacterial soaps and/or disinfectants minimizes infection. Hands should be thoroughly cleaned prior to eating, drinking, or other hand-to-mouth activities. Care should also be taken not to swipe debris from the eyes with soiled fingers during any work activity involving refuse or contact with soil.

EMERGENCY MEDICAL CARE: Permanent first aid equipment will not necessarily be found on site; first aid kits are kept in PPE bags as well as in company trucks. List of emergency phone numbers:

Agency/Facility	Telephone Number
Ambulance	911
Police	911
Fire	911
Hospital	911
SCS Long Beach Office	(800) 326-9544
Project Leaders	
Northern California	
Wayne Pearce – cell phone	(916) 251-6425
Southern California	
Ray Huff – cell phone	(562) 355-6334

EMERGENCY PROCEDURES: Stop work activities when injury or accident occurs. As needed notify appropriate emergency agency. Administer first aid if possible. Contact the SCS Project Manager and Health & Safety Coordinator as soon as possible.

APPROVAL SIGNATURE: ____

All site personnel have read the above plan and are familiar with its provisions.

	Name	Signature	Date
Project Team Leader:	____________________	_______________	______________
Health & Safety Officer:	____________________	_______________	______________
Other Site Personnel:	____________________	_______________	______________
	____________________	_______________	______________

Appendix B
Probe Functionality Investigation Summary and Determination

This appendix contains spreadsheets (MS Excel 2 MB) with all pertinent data obtained from the landfill gas probe functionality study for each of the 20 study landfills.
These spreadsheets are not included in this document but can be downloaded from the CIWMB website.
This data is categorized by site and actual probe number and includes (for each probe) initial probe conditions, all collected gas monitoring data, vacuum testing results, video borescope findings, a lithology evaluation, and a determination of probe functionality.

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